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ABSTRACT

A research project involving 16 experiments investigated the nature of the encoding process for verbal materials, particularly differences arising from mode of presentation. The results showed that a change in mode of presentation of items produced a recovery from interference in short term retention. Since intermodal interference was lower than intramodal interference it appeared that auditory and visual items were represented by different memory codes in the short-term store. However, since recovery from interference depended on the nature of the intervening information received by the subject, it seemed to follow that the memory code was subject to task demands and under the subject's control. Other data showed that proactive interference depended partly on long-term processes and was due to retrieval difficulties. Some of the experiments were preliminary attempts to develop techniques for studying the attributes of memory, such as by testing the subject for his memory of particular properties of the stimulus, for example, the modality in which it was presented. (Author/PB)

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Final Report

Project No. 10628
Grant No. OEG-X-71-0032(508)

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# THE ENCODING OF VERBAL INFORMATION

June, 1973

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Author Abstract

The experiments of this project have shown that a change in mode of presentation of items produces a recovery from interference in short-term retention. The fact that intermodal interference is lower than intramodal interference provides strong support for the hypothesis that auditory and visual items are often represented by different memory codes in the short-term store. However, the recovery from interference depends in a critical way on the nature of the intervening information received by the subject. Consequently, the memory code is subject to task demands and probably under the subject's control. Related experiments investigated the nature of proactive interference, showing it to depend in part on long-term processes and to be largely due to retrieval difficulties. Several experiments were preliminary attempts to develop other techniques for studying the attributes of memory. One particularly promising procedure is to simply test the subject for his memory of very particular properties of a stimulus, such as the modality in which it was presented.

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Table of Contents


| | | Page |
|---|---|---|
| Ch. 1 | Introduction | 1 |
| | Background | 1 |
| | Objectives | 3 |
| | Organization of the Report | 3 |
| | General Method | 4 |
| Ch. 2 | Results | 6 |
| | Shift in Presentation Modality and Release from PI | 6 |
| | Exp. I: The Attention Hypothesis | 6 |
| | Exp. II: Distractor Modality | 7 |
| | Exp. III: Replication of Distractor Modality | 10 |
| | Exp. IV: Mixed-Modality Distractor and a Mixed-List Procedure | 11 |
| | Exp. V: Mixed-Modality Distractor with Homogeneous Lists | 15 |
| | Exp. VI: Filler-Task Verbalization with the Mixed-Modality Filler | 17 |
| | Exp. VII: Rate of Presentation | 17 |
| | Characteristics of PI in this Situation | 20 |
| | Exp. VIII: The Dissipation of PI during a 120-Second Rest | 20 |
| | Exp. IX: Rest-Interval Difficulty and the Dissipation of Proactive Interference | 23 |
| | Exp. X: Retrieval Processes in PI with Experimentally Familiarized Materials | 23 |
| | Exp. XI: PI as a Function of Retention Interval with Items Known to be Present in Memory | 24 |
| | Exp. XII: Mode of Presentation and PI with a Long Recall Period | 25 |
| | Other Procedures for Studying Encoding | 28 |
| | Exp. XIII: Direct Measurement of Memory for Mode of Presentation | 28 |
| | Exp. XIV: Acoustic and Visual Similarity in Same-Different Letter Identification Judgments | 31 |
| | Exp. XV: Pronunciation Effects in Forced-Choice Recognition Memory | 32 |
| | Exp. XVI: Pronunciation Effects in Old-New Recognition Memory | 34 |
| Ch. 3 | Conclusions and Recommendations | 37 |
| | References | 38 |

## Chapter 1: INTRODUCTION

Background. The multi-store conception of memory dates at least to James (1890) and was given its most familiar contemporary description by Atkinson and Shiffrin (1968). While there is some disagreement on details, the model proposed by Atkinson and Shiffrin is generally representative of the approach of Waugh and Norman (1965), Broadbent (1958, 1970), and Neisser (1967) among others. According to this view, the memory system consists of three basic components: (a) a sensory register which holds a veridical copy of the stimulus for a few hundred msec; (b) a short-term store which can hold information for a few sec and serves as a working memory and input-output system for the long-term store; and (c) a long-term store which is a relatively permanent repository for an individual's experiences. There is a good deal of evidence for this conceptualization, much of it recently reviewed by Kintsch (1970). Although some writers have also argued against this characterization of memory (e.g., Craik & Lockhart, 1972; Melton, 1963), it has, nevertheless, proved to be an extremely useful heuristic device for the behavioral study of memory, and will be adopted here as a working assumption.

It is apparent that, regardless of one's conceptualization of the memory system, an organism does not store a perfect representation of the stimulus. This fact has been emphasized by a number of theorists, perhaps none more clearly than Underwood (1963) in his distinction between the nominal stimulus (as presented by the experimenter) and the functional analog of this stimulus (perceived and stored by the subject). The encoding of a stimulus is the perceptual process by which the sense receptors and central nervous system translate the stimulus into the internal representation which is stored in the memory system. The form in which it is thus recorded is the memory code. At the behavioral level, a common assumption is that a memory code functions as though it were a list of features or attributes of the to-be-remembered event (Bower, 1967; Underwood, 1969; Wickens, 1970), and this is the view adopted here. It follows that one of the fundamental problems for students of memory is to identify the basic attributes of memory, and to determine how these attributes are encoded or selected, and what role they play in the functions of memory. This problem has received a great deal of recent attention (Melton & Martin, 1972), though it is obvious that much remains to be done.

Underwood (1969) has suggested that one of the fundamental attributes of memory is the modality, auditory (A) or visual (V), of stimulus presentation. The primary function of this attribute is probably to discriminate among memories (Underwood, 1969, 1972); it is one of the attributes useful as a discriminative cue but not necessarily as a retrieval cue in the usual sense of that word. In laboratory situations, presentation modality may be an extremely useful discriminative cue for long-term memories. However, our long-term memories are so crowded by "real-life" information received in either the A or V mode, this attribute may have much less utility for discriminating among non-laboratory long-term memories. The situation would seem to be quite different in the short-term store. The rapid turnover of limited amounts of stimulus information may make memory for stimulus modality an extremely useful discriminative cue in the latter store. Thus, it seems important to know if, and under what conditions, information

concerning stimulus modality is coded in the short-term store. That problem was primary focus of this research project.

One view is that the short-term memory code is primarily acoustic or articulatory, regardless of the modality of stimulus presentation. There are a variety of reasons for this assumption, both empirical and theoretical. First, rehearsal is an important function of the short-term store (Atkinson & Shiffrin, 1968). It has been proposed by a number of theorists (e.g., Adams, 1967; Sperling, 1967) that rehearsal translates V material into an acoustic or articulatory mode, resulting in a short-term code that is the same as for A materials. Strong support for this assumption is provided by studies showing a striking similarity between confusion errors in identification of letters presented in the A mode and confusion errors in memory for letters presented in the V mode (Conrad, 1964; Wickelgren, 1965). A second type of evidence is provided by a large number of studies of interference effects among semantically and acoustically similar materials. For example, Kintsch and Buschke (1969) reported that short-term retention was unaffected by semantic similarity but was reduced by acoustic similarity, whereas the converse was true for long-term retention. Finally, the short-term store seems to be much more efficient in handling A materials than V materials (Grant & McCormack, 1969; Murdock, 1967, 1968; Murdock & Walker, 1969).

There is little doubt that the short-term memory code is often acoustic/articulatory in nature, and that there is an emphasis on semantic features in the long-term store. However, there is accumulating evidence that modality information, per se, is represented in the memory code. Concerning the short-term store in particular, the evidence presented above for acoustic/articulatory coding can be countered by four specific arguments.

The first counter argument is the empirical contradiction to the assumption that rehearsal translates V items into an A type of memory code. There is accumulating evidence that subjects can rehearse in a V or imaginal mode (Atwood, 1971; den Heyer & Barrett, 1971). The mechanism for rehearsal is not clear, but the assertion that rehearsal is equivalent to covert verbalization seems to have been an oversimplification. The second argument concerns the evidence from experimental manipulations of similarity. Schulman (1971) recently reviewed the effects of similarity on short-term retention, and concluded that the short-term memory code is not always acoustic/articulatory in nature. Instead, task demands can result in semantic codes. The same is probably true for V codes. Related to the evidence from manipulations of similarity is the often-overlooked logical inconsistency: the short-term store is presumed to serve as an input-output system for the long-term store, but it is hypothesized that the memory code is entirely different in the two cases. Logically, it would seem that any code differences must be a matter of emphasis. Finally, as suggested by Murdock and Walker (1969), the fact that the short-term store processes A information more efficiently than V information may, itself, be taken as a clear indication for distinct memory codes in the two cases.

On the basis of the conflicting evidence reviewed above, and because of the potential significance of modality-specific encoding, the problem

seemed to require further investigation. The technique used in many of the experiments of this project was that developed by Wickens and his associates (Wickens, 1970; Wickens, Born, & Allen, 1963) for the study of interference effects between different classes of materials. Simply stated, the rationale in using interference effects to study encoding is that materials which don't interfere with one another must be, to some extent, represented by different memory codes, i.e., encoded differently. The particular type of interference studied most widely in this context has been proactive interference (PI), which develops over successive trials (Keppel & Underwood, 1962) in the distractor type (Brown, 1958; Peterson & Peterson, 1959) short-term retention task. The important fact for present purposes is that a number of experiments have demonstrated that certain changes in materials and/or procedures, following the development of PI, result in an abrupt improvement in performance, or release from PI. This release-from-PI phenomenon has been taken as evidence of differential encoding and is widely used to study encoding processes (Wickens, 1970, 1972).

In initial experiments that provided the basis for this project, the writer and his students (Hopkins, Edwards, & Gavelek, 1971; Hopkins & Gavelek, 1970) reported that a shift to A presentation following several successive V trials produced a significant recovery from interference, supporting the notion that A and V materials are encoded differently for short-term retention. However, a comparable shift in the A to V direction did not reduce interference. All other factors being equal, it seemed logically impossible for the encoding to be different for the two modalities when assessed by a shift from V to A presentation, but not when assessed by an A to V shift. Thus, it was assumed that other uncontrolled variables were very important in this situation, or that the release-from-PI paradigm is unsatisfactory for the study of encoding processes. The purposes of the proposed project, then, were to clarify these results and, hopefully, to shed new light on the controversy regarding the encoding of presentation modality in the short-term store.

Objectives. The general objective of the project was to investigate the nature of the encoding process for verbal materials, particularly differences arising from mode of presentation. Somewhat more specifically, the objectives may be divided into three parts, although these parts are not mutually exclusive:

(1) To determine some of the important conditions producing differential encoding of A and V materials, as evidenced by a release from PI following a shift in the mode of presentation of the stimulus materials.

(2) To investigate some of the characteristics of the PI which develops over repeated trials in the distractor procedure.

(3) To make some initial attempts to study encoding using a variety of procedures other than the release-from-PI paradigm.

Organization of the report. Since the project was concerned primarily with empirical research, most of the report will be contained in the results section. A number of experiments were conducted, and these will

be discussed and evaluated as they are presented. The report will also include a rather brief section on conclusions and recommendations; the latter section will summarize the important findings, evaluate their significance, and make recommendations for future research and applications. A number of methodological considerations were common to many of the experiments to be reported. Although a slight departure from the recommended format, in the interest of clarity and brevity these general features will be described next.

General method. The subjects were Washington State University undergraduates who participated in partial fulfillment of course requirements. The subjects were either totally naive with respect to verbal learning experiments, or had not served in other experiments using the same materials and procedures. The subjects were always assigned to treatments randomly with the restriction that the nth subject not be assigned to a particular treatment until n-1 subjects had been assigned to each of the other treatments in a particular experiment.

In all experiments in which the two modes of presentation were directly compared, the A stimuli were prerecorded on a stereo tape deck and presented via headphones or loudspeaker. The V stimuli were presented on a rear-projection screen by a pair of alternating slide projectors. These projectors were equipped with external shutters for precise control of exposure duration at 0.5 sec, approximately the duration of A stimuli. Synchronization of A and V stimuli, as well as control of temporal parameters, was accomplished by programming equipment designed and constructed under the support of this project (Hopkins, 1972).

The most commonly used procedure in this project was the Brown-Peterson (Brown, 1958; Peterson & Peterson, 1959) short-term retention task. In this task, a set of three or four words are presented for the subject to study and remember. The study period is followed by a period of 20 sec, or less, of distractor activity such as a simple arithmetic or classification task. The purpose of this filler activity is to prevent rehearsal. The rehearsal-prevention activity is followed by a recall period of a few seconds. Then the next trial begins immediately. On each trial, the subject need recall only the words from that particular trial, and is so informed. Nevertheless, recall performance in this task typically drops over a series of several successive trials from nearly perfect recall on the first trial to recall of only about one out of three study words on the third trial. This decrement in performance is attributed to PI.

Most of the release-from-PI experiments involved a shift in mode of presentation and require a minimum of four conditions, two experimental and two control. The experimental condition in which presentation is shifted from A to V requires a control condition in which stimulus presentation is V on all trials. The experimental condition in which presentation modality is shifted from V to A requires a control condition in which presentation is via the A mode on all trials. These conditions will be referred to by a two-letter appreviation in which the first letter refers to the mode of presentation on the pre-shift trials and the second letter to the presentation modality for the shift trial. For example, Condition AV refers to a

treatment in which several A trials are followed by a shift to V presentation; Condition VV refers to a treatment in which all trials are V trials.

## Chapter 2: RESULTS

### Shift in Presentation Modality and Release from PI

The first seven experiments to be described were conducted with two related purposes. First, they were designed to provide an explanation of the asymmetrical release from PI obtained by Hopkins, Edwards, and Gavelek (1971). The second purpose was a natural byproduct of this investigation: a number of important variables were tested to determine their role in the release-from-PI paradigm.

### Exp. I: The Attention Hypothesis (Hopkins, Edwards, & Cook, 1973)

Hopkins, Edwards, and Gavelek (1971) suggested the "attention hypothesis" as one possible explanation for the asymmetrical release from PI in their experiment. According to this hypothesis, subjects in the A to V shift condition stopped attending to the V display after several successive A trials, even though warned at the outset that a shift in modality might occur. If this hypothesis were correct, many subjects would not have perceived the V materials of the A to V shift and, consequently, could not have demonstrated the release from PI. Although internal analyses of the earlier data did not support the attention hypothesis, it was not tested directly. In the present experiment, an attempt was made to assure that the subject attended to the visual display. He was simply informed at the beginning of each trial of the mode of presentation to be used.

Method. Each subject received four successive trials in a distractor-type short-term retention task. The conditions of study remained constant for each subject over the first three trials. The fourth trial was a shift trial to test for release from accumulated PI. Four independent groups were formed by the factorial combination of mode shift (present or absent) and mode of presentation on the fourth trial (A or V). Thirty-two subjects were assigned to each of the four groups.

The to-be-recalled study items were triads of high-frequency animal names from the Battig and Montague (1969) norms. Two different lists were prepared by independently forming four triads from the word pool; these lists were counterbalanced across the conditions. The distractor or filler materials on each trial were a randomly selected series of six signed digits from the pool +1, -1, +2, and -2. When a +1 or a -2 was presented, the subject was to say "A"; when a -1 or a +2 was presented, the subject was to say "B."

Each trial began with a warning signal which informed the subject of the mode of presentation for the upcoming trial. For V trials, this signal was the word "visual" presented simultaneously on the screen and over the headphones; for A trials, the word "auditory" was presented simultaneously in both modalities. After 1.5 sec, the study words were presented one at a time at intervals of .75 sec, onset to onset. The first filler item was presented .75 sec after the onset of the last study word. The six filler items were then presented at intervals of 2.5 sec, onset to onset. As in the Hopkins, Edwards, and Gavelek (1971) experiments, the filler items were presented in the V modality on all trials. After the last filler item, the

word "recall" was presented on the screen and the subject had 2.5 sec to say aloud the three study words. There was no intertrial interval; the warning signal for the next trial was presented immediately after the recall period. This procedure was repeated without interruption for four trials.

Results and discussion. The mean numbers of words correctly recalled are presented in Figure 1 as a function of trials. Performance on Trials 1 to 3 was analyzed first. As may be seen in the figure, recall declined markedly from the first to third trials, $F(2,248) = 104.05$, $p < .001$, indicating rapid development of substantial PI. The only other significant source of variance was that A items were recalled better than V items, $F(1,124) = 22.65$, $p < .001$. This difference between the two modes is consistent with a variety of previous results (Hopkins, Edwards, & Gavelek, 1971; Grant & McCormack, 1969).

Analysis of the shift results from Trial 4 would ordinarily involve the comparison of Condition VA to its control Condition AA and the comparison of Condition AV to its control Condition VV. However, this analysis could be misleading because the apparent Trial 4 superiority of Condition AV to Condition VV may be entirely due to carryover from the main effect of mode on Trials 1 to 3. Consequently, absolute release from PI was evaluated by using recovery scores. The recovery score was computed for each subject by subtracting Trial 3 recall from Trial 4 recall. The mean recovery scores may be estimated from Figure 2, and are 1.03, -.06, -.41, and -.13 for the VA, AA, AV, and VV conditions, respectively. The only one of these mean recovery scores which was significantly different from 0.0 was that for Condition VA, $t(31) = 4.30$, $p < .001$. It is concluded that under these conditions there is a release from PI for a VA shift but not for an AV shift. Therefore, the warning signal was unsuccessful in producing a symmetrical release from PI, and the attention hypothesis is discredited.

## Exp. II: Distractor Modality (Hopkins, Edwards, & Cook, 1973)

All of our previous experiments had used an interpolated task presented in the V mode. This experiment was simply designed to assess the role of filler modality in this situation. There are a number of indications in the literature that a distractor task interferes more with retention when it is presented in the same mode as the study items than when the study and distractor modes differ (Kroll, Parks, Parkinson, Bieber, & Johnson, 1970; Margrain, 1967; Parkinson, 1972). Thus, it was predicted that the direction of the main effect of modality would depend on the filler modality; furthermore, it seemed likely that the filler modality might influence the asymmetry in the release from PI.

Method. Eight independent groups were formed by the factorial combination of mode shift (present or absent), mode of the memory items on the shift trial (A or V), and mode of the filler task (A or V). This experiment was conducted simultaneously with Exp. I, with only two differences in materials and procedure. First, the warning signal at the beginning of each trial was replaced by the word "study" for continuity with the procedure of Hopkins, Edwards, and Gavelek (1971). Secondly, the filler items were presented

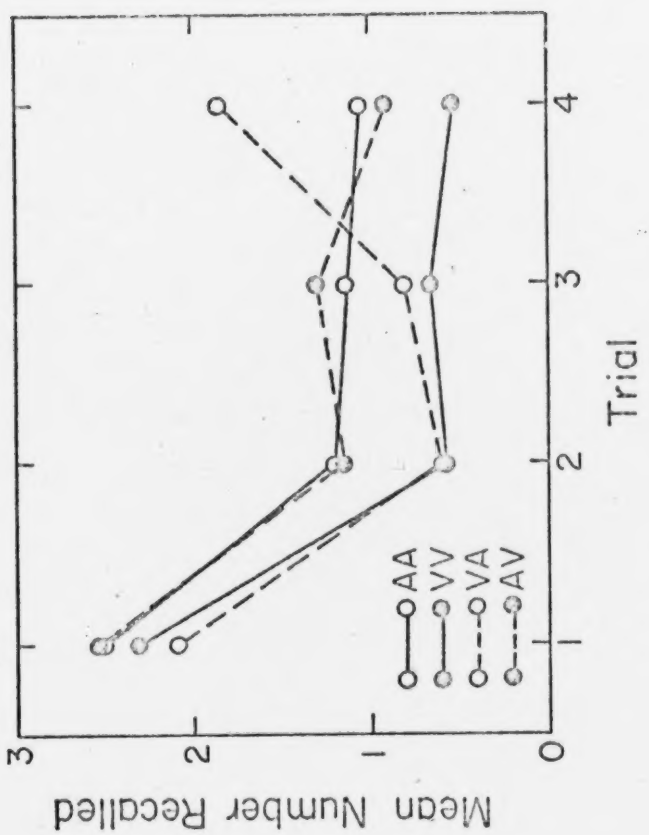


Fig. 1. Mean numbers of words correctly recalled in Exp. I.

in the assigned modality via the screen or headphones. The subject always verbalized the response to each filler item. Thirty-two subjects were assigned to each group.

Results. The mean recall scores are presented in Figure 2, with the curves for the V filler in the left panel and for the A filler in the right panel. Considering first the data for the development of PI, performance on the first three trials was analyzed with filler mode, presentation mode, shift, and trials as variables. Obviously, recall declined across the first three trials, $F(2,496) = 157.48$, $p < .001$. Overall, recall was better with the V filler than with the A filler, $F(1,248) = 16.94$, $p < .001$, and recall was better for words presented in the A mode than for V words, $F(1,248) = 8.71$, $p < .005$. However, presentation mode and filler mode interacted reliably, $F(1,248) = 33.40$, $p < .001$, such that with a V filler, recall of A items was better than that of V items, $F(1,248) = 38.12$, $p < .001$; but with an A filler, recall of V items was better than that of A items, $F(1,248) = 4.00$ $p < .05$. Unfortunately, there was an interaction between filler mode and shift, $F(1,248) = 6.86$, $p < .01$. The nature of this interaction was such that the recall of shift groups was poorer than that for no-shift groups for the A filler condition, but that the reverse was true for the V filler condition. Since the shift and no-shift conditions were treated identically on the first three trials, the differences must be due to sampling error. Furthermore, although this interaction may have attenuated the release from PI in the A filler conditions and enhanced it in the V filler conditions, it almost certainly could not account for the particular pattern of results obtained on Trial 4.

Turning to the shift data, the recall scores from Trial 4 were analyzed with presentation mode, shift, and filler mode as variables. The three-way interaction of these variables was significant, $F(1,248) = 11.49$, $p < .001$, so the data were analyzed separately for the V filler and for the A filler conditions. With a V filler, A presentation of the study words produced better recall than V presentation, $F(1,124) = 54.04$, $p < .001$, and a mode shift produced better recall than no shift, $F(1,124) = 10.46$, $p < .005$. However, as shown in Figure 2, the shift effect was confined entirely to the VA condition, resulting in a mode by shift interaction, $F(1,124) = 10.46$, $p < .005$. For the V filler, then, the results confirm those obtained in Exp. I and by Hopkins, Edwards, and Gavelek (1971). With an A filler, V presentation of the study words produced better recall than A presentation, $F(1,124) = 5.11$, $p < .05$, and a shift produced better recall than no shift, $F(1,124) = 16.55$, $p < .001$. In this case, the interaction between mode and shift was not reliable, $F(1,124) = 2.95$, $p = .09$. However, it is apparent in Figure 2 that recall was better in Condition AV than in the VV control, $F(1,124) = 16.74$, $p < .001$, whereas recall in Condition VA was little, if any, better than that in the AA control, $F(1,124) = 2.76$, $p > .10$. These conclusions were confirmed by analyses of the Trial 4 minus Trial 3 recovery scores. For the V filler, the mean recovery score was significantly different from 0.0 only in Condition VA, $t(31) = 8.36$, $p < .001$; for the A filler, the mean recovery score was significantly different from 0.0 only in Condition AV, $t(31) = 5.56$, $p < .001$. It is concluded that an asymmetrical release

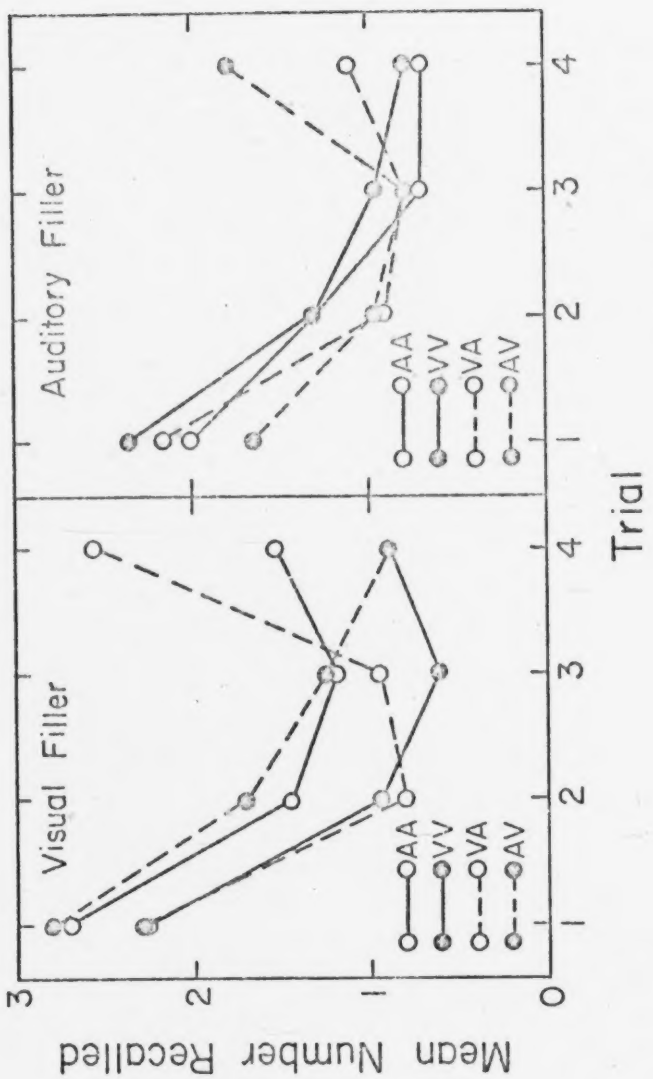


Fig. 2. Mean numbers of words correctly recalled in Exp. II.

from PI is obtained with both an A filler and a V filler, and that the direction of the asymmetry can be manipulated by changing the mode of the filler task. These results will be discussed after presentation of the results of a replication experiment.

Exp. III: Replication of Distractor Modality

Because of the particularly interesting, and important, outcome of Exp. II, the next experiment was conducted to provide a replication and extension of those results.

Method. Twenty-eight subjects were assigned to each of the eight conditions. The lists and procedure were similar to Exp. II with the exception that a different distractor task was used to increase the generality of the results. The interpolated task required simple addition of two digits. The digits were presented in pairs; the subject simply added the digits of each pair and pushed one button if their sum was odd and a second button if their sum was even. The digits were randomly selected with the restriction that none was zero. The same 28 digit pairs, seven per trial, were used in all lists. The members of a digit pair were presented successively in either the A or V mode with a 1-sec interval (onset to onset) between the presentation of the first digit and second digit of a pair; the interval between the onset of the second digit and the next digit pair was 1.5 sec. Subjects were given practice on the filler task until they had mastered it; usually one trial through a practice list of 10 pairs was sufficient.

Results. For brevity, only the Trial 4 minus Trial 3 recovery scores will be presented here. With an A filler the mean recovery scores were .61, -.18, .00, and -.07 for Conditions AV, VV, VA, and AA, respectively. The corresponding means for the V filler conditions were -.50, -.18, 1.39, and -.14, respectively. The only two mean recovery scores that were reliably different from zero were that for Condition AV with an A filler, $t(27) = 2.31$, $p < .05$, and that for Condition VA with a V filler, $t(27) = 5.37$, $p < .001$. Thus, these results replicate those of Exp. II.

Discussion. The results of Exps. I, II, and III are quite clear on the asymmetrical release from PI following a shift in mode of presentation: (1) The earlier finding (Hopkins, Edwards, & Gavelek, 1971) of a release from PI following a VA shift, but not an AV shift, can be replicated. (2) The asymmetry is not changed by warning the subject of the mode of presentation at the beginning of each trial; the attention hypothesis is incorrect. (3) The direction of asymmetry in the release from PI can be completely reversed by presenting the interpolated task in the A mode rather than in the V mode. (4) When the distractor task is presented in the A mode, it interferes more with the retention of A memory items than with V items; presenting the distractor task in the V mode results in more interference with V memory items than with A items.

It is assumed that items which don't interfere with one another must, to some extent, have different memorial representations. Given this assumption, these results clearly suggest that A and V materials are,

at least under some conditions, encoded differently. That is, there are two different indications that intermodal interference is lower than intramodal interference. First, recall is better when the modes of presentation of the distractor and to-be-remembered items are different than when those modes are the same. Secondly, under appropriate conditions, a release from PI is obtained following a shift in the mode of presentation of the memory items.

These results also bear on the question of the locus of the PI effects. The theoretical implications would seem to be most interesting if the processes producing the observed effects are in the short-term store. It is reasonable to eliminate a pre-categorical store (Crowder & Morton, 1969; Neisser, 1967) as the possible locus on the grounds that the retention intervals used here exceed the lifetimes ordinarily associated with items in the pre-categorical store. On the other hand, it has been suggested that some portion of the release from interference observed in this paradigm reflects long-term, as opposed to short-term, processes (cf., Exps. VIII and IX of this report). In fact, Craik and Birtwistle (1971), using a free recall procedure, concluded that the release from PI is due entirely to long-term processes. Nevertheless, most memory theorists assign rehearsal processes to the short-term store, and the results of Exps. II and III clearly show that a variable which affects rehearsal, the nature of the distractor activity, has a profound effect on the release from PI. Thus, in contrast to the free recall procedure, the release from PI obtained in the short-term distractor task, and any inferred encoding differences, seem to reflect primarily processes operating in the short-term store.

These results, then, are taken as evidence that A and V materials can have different representations in short-term memory. This is not to say that an auditory and/or articulatory code does not play a major role in verbal short-term memory, or even that the code for V items is visual or imaginal in nature. It is simply suggested that not all verbal items are stored as though they had been presented in the A mode, and that theories of memory will need to take account of this fact.

Exp. IV: Mixed-Modality Distractor and a Mixed-List Procedure (Hopkins, Edwards, Tamayo, Holman, & Cook, 1973)

The next three experiments used a mixed-mode interpolated task to explore further the role of the rehearsal-prevention activity in the encoding of A and V words. The digit-addition filler task was used for these experiments. However, the digits of a pair were presented simultaneously, one in the A mode and one in the V mode. Thus, each filler item required processing of both A and V information. On the basis of the results of Exps. II and III, it was predicted that this type of interpolated task should interfere equally with the retention of A and V information. Thus, to the extent that a release from PI is obtained, it should be symmetrical. If this prediction were confirmed, then the mixed-mode filler task could be used in future experiments on modality effects in the release-from-PI paradigm to reduce the required number of conditions by a factor of two.

In Exp. IV an additional procedural change was made: some of the study words were presented in the A mode and some in the V mode on each trial. This procedure had never been used before in the release-from-PI paradigm. However, this mixed-list procedure has several potential advantages over the usual homogeneous lists. In addition to a reduction in the number of treatment groups required, the mixed-list procedure permits the observation of certain processes in the statistically more powerful within-subject design. For example, the mode by trials interaction, which would indicate differential rates of PI development, is difficult to detect in the usual between-subject design but might be detectable in the within-subject design.

Method. Each subject received four successive trials in the distractor-type short-term retention task. On each trial, four words were presented for the subject to study, followed by an interpolated task to prevent rehearsal, and then recall. There were three independent groups. In Condition AM (auditory shifting to mixed presentation), all words were presented in the A mode for the first three trials; on Trial 4, two of the words were presented in the A mode and two were presented in the V mode. Similarly, in Condition VM, all words were presented in the V mode on Trials 1 to 3, but two were presented in the A mode and two in the V mode on Trial 4. In the control Condition MM, two words were presented in the A mode and two in the V mode on each of the four trials. Forty-eight subjects were assigned to each of the three groups.

The following describes the lists for Condition MM. The words were 16 different animal names selected from the Battig and Montague (1969) norms. Four different 4-tuples of these words were formed such that the mean category frequency was approximately the same for each of the 4-tuples. Four basic lists were then prepared with the assignment of 4-tuples to trial positions counterbalanced. Within each 4-tuple two words were assigned to the A subset and two to the V subset, such that each of the following serial orders of the two subsets was used for exactly one of the 4-tuples: AVAV, VAVA, VAAV, and AVVA. Then the assignments of words to the A and V subsets were counterbalanced, making two forms of each basic list for a total of eight lists. Identical lists were constructed for Condition AM and Condition VM. The A and V subsets were, of course, merely a counterbalancing factor on Trials 1 to 3 of these latter conditions.

The interpolated task was the two-digit addition task. For each pair of digits, one digit was presented in the A mode and one in the V mode, and the subject was instructed to simply report the sum. The digits were randomly selected with the restriction that none was zero. The same 32 digit pairs, eight per trial, were used in all eight lists.

The word "study" was presented at the beginning of each trial; 2 sec later the words of a 4-tuple were presented at a rate of one word per sec. The first digit pair was presented 1 sec after the onset of the last study word; the A and V digits were presented simultaneously at a rate of one pair each 1.5 sec. The word "recall" followed the eighth digit pair by 1.5 sec, and the subject was allowed 3 sec for recall. The next trial began immediately with no intertrial interval.

Each subject was instructed concerning the various types of presentation and the possibility of a shift in mode of presentation. Each subject was given practice on the filler items until he was completely familiar with the task; usually one trial through a list of 10 practice pairs was sufficient.

Results. The mean numbers of words correctly recalled are presented in Figure 3, where recall performance is shown separately for subsets A and V on all trials. This method of presenting the data provides for the same maximum score of two correct in all conditions. However, it must be remembered that both subsets were presented in the A mode on Trials 1 to 3 of Condition AM and in the V mode on Trials 1 to 3 of Condition VM. Thus, there should be no difference in recall between the A and V subsets of these two conditions for the first three trials.

The data for the first three trials were analyzed with item subset, condition, and trials as variables. Obviously, there was a significant decrement in recall scores across the first three trials, $F(2,282 = 78.74)$, $p < .001$, presumably due to the development of PI. The only other significant sources of variance were condition, $F(2,141) = 3.24$, $p < .05$, and the interaction between item subset and condition, $F(2,141) = 6.16$, $p < .005$. These latter two effects are apparently both due to depressed performance on A items of Condition MM. Followup tests confirmed this, showing that recall of A items was lower than that of V items in Condition MM, $F(2,141) = 13.49$, $p < .001$; however, as expected, the two subsets were not significantly different in either Condition AM or VM, both $F$s $< 1$. Although the mean recall score (pooled over trials and subsets) was slightly higher for Condition VM than for Condition AM ($\bar{X} = 1.05$ versus $\bar{X} = 1.01$), this difference was clearly not reliable, $F < 1$. Thus, under these conditions, short-term retention is better for items presented in the V mode than for items presented in the A mode, but the difference is significant only in the mixed-list comparison of Condition MM. Since none of the interactions with trials was reliable, the effect of mode of presentation on the rate of development of PI was not significant for either the mixed-list or homogeneous-list comparisons.

Turning to the shift data from Trial 4, a release from PI following a V to A shift would be indicated if the A subset of Condition VM were better recalled than the A subset of Condition AM and of the control Condition MM. It is apparent in the left panel of Figure 3 that Trial 4 performance was not better for Condition VM than for Condition AM, though observed performance for Condition MM was somewhat lower. In fact, the effect of condition on Trial 4 recall of items from the A subset did not reach normally accepted standards of reliability, $F(2,141) = 3.44$, $p = .07$. On the other hand, a release from PI following an A to V shift is indicated if the V subset of Condition AM is better recalled than the V subset of the other two conditions, and it may be seen in Figure 3 that this was the obtained result, $F(2,141) = 8.02$, $p < .01$.

Discussion. It is apparent that, under the present conditions, the release from PI following a shift in mode of presentation is once again

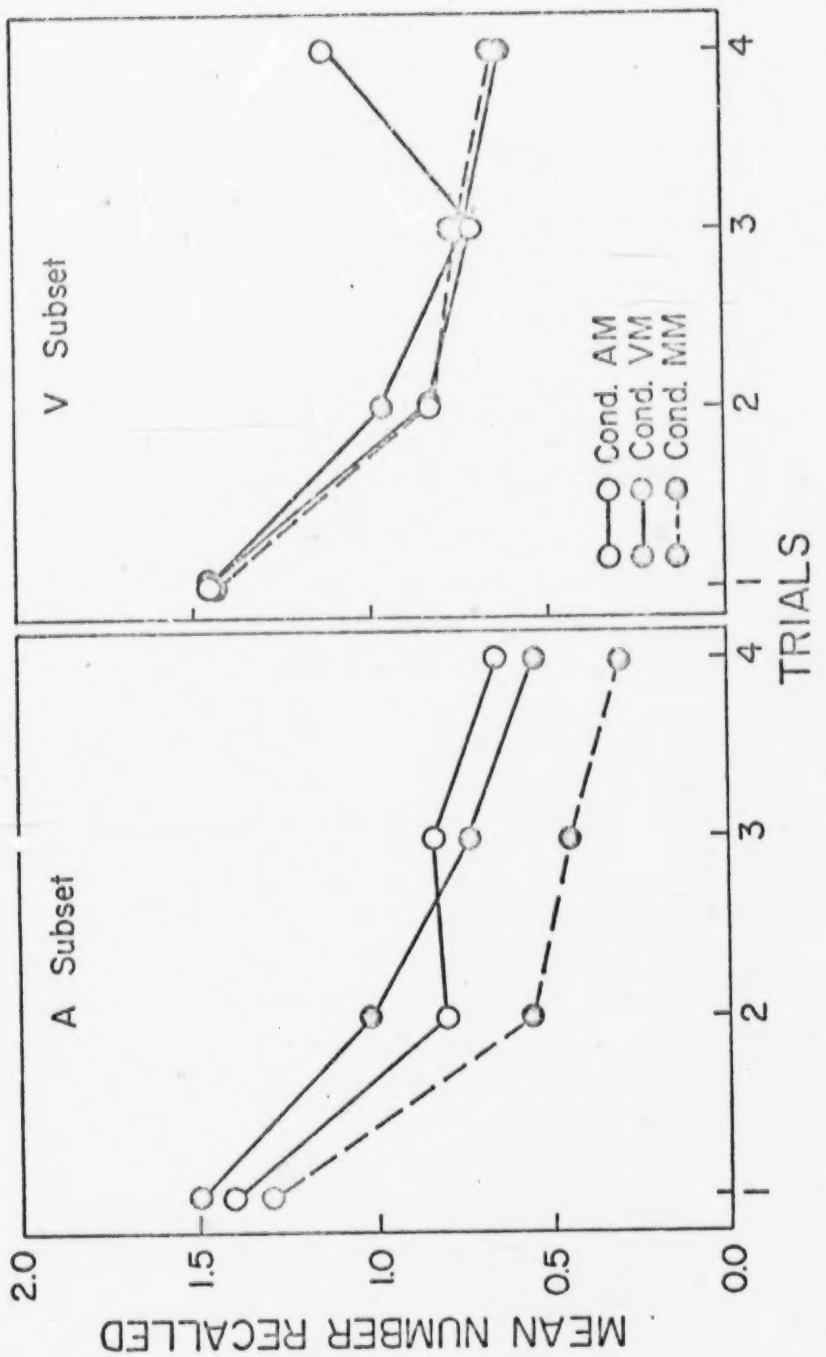


Fig. 3. Mean numbers of correct responses in Exp. IV.

asymmetrical. The release occurs for an A to V shift but not for a V to A shift. What might account for the asymmetry in this experiment? One factor which may have contributed to the outcome of this experiment was the use of mixed lists. Since mixed lists have not previously been studied in the release-from-PI situation, some unknown aspect of that procedure could have produced the unexpected results. For this reason, another experiment was conducted. The mixed-mode filler was again employed, but independent groups were assigned to the shift and control conditions learning triads of words homogeneous with respect to mode of presentation on each trial.

Exp. V: Mixed-Modality Distractor with Homogeneous Lists (Hopkins, Edwards, Tamayo, Holman, & Cook, 1973)

Method. Mode shift and mode of presentation on Trial 4 were orthogonally combined to yield two experimental and two control groups. The interpolated task and general procedure were identical to Exp. IV. However, the to-be-remembered materials consisted of triads of animal names rather than 4-tuples. Four different lists were prepared by forming four triads of animal names and assigning each triad to a different trial in each list. The lists were counterbalanced across conditions. Thirty-two subjects were assigned to each condition.

Results. The mean numbers of words correctly recalled are presented in Figure 4. Considering first the development of PI, the data from the first three trials were analyzed with presentation mode, shift, and trials as factors. The only reliable source of variance was that of trials, $F(2,248) = 76.35$, $p < .001$, indicating substantial development of PI. On Trial 4 there was a release from PI following an A to V shift, as evidenced by the fact that recall was better in Condition AV than in the control Condition VV, $t(62) = 3.93$, $p < .001$; the difference between Condition VA and its control Condition AA was not significant, $t < 1$. Thus, the asymmetrical release from PI observed in Exp. IV is also obtained with independent groups.

Discussion. Using a mixed-mode filler, a release from PI is obtained for an A to V shift but not for a V to A shift. The conclusion is the same for the mixed-list procedure of Exp. IV as for the independent-groups design of Exp. V. The obtained asymmetry is remarkably similar to that observed when the filler task is presented in the A mode (Exps. II and III), and opposite to that obtained with a V filler (Exps. II and III; Hopkins, Edwards, & Gavelek, 1971). Thus, it appears that the mixed-mode filler has some of the functional characteristics of an A filler task.

The results of this experiment and that of Exp. IV are consistent with the conclusion of Exps. II and III that the similarities in and differences between the representations of A and V memory items in the short-term store depend in a critical way on the mode of presentation of the filler activity. Kroll, Bee, and Gurski (1973) have also reached a similar conclusion. On the other hand, these experiments were unsuccessful in demonstrating that a mixed-mode interpolated task would produce a symmetrical reduction in interference following a shift in mode of presentation of the memory items. Indeed, the mixed-mode filler seems to have the same effect as an A filler. The reason

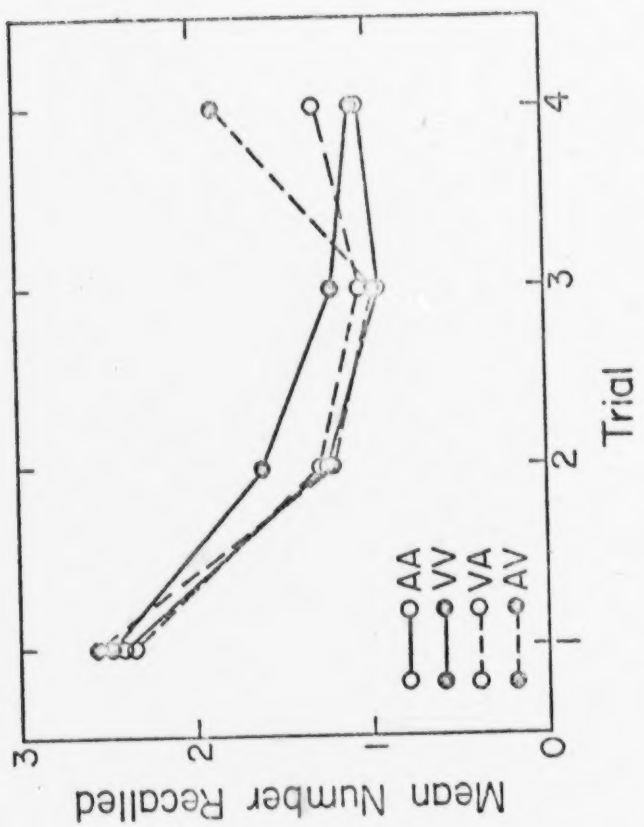


Fig. 4. Mean numbers of words correctly recalled in Exp. V.

for this fact is simply not clear. One can, of course, generate vague, ad hoc hypotheses suggesting the dominance of an A component in the subject's information-processing system, or that the subject prefers to process the A members of the filler items. The fact remains, however, that in order to perform at the observed high level on this filler task (89% correct), the subject must process both A and V components.

Exp. VI: Filler-Task Verbalization with the Mixed-Modality Filler (Hopkins, Edwards, Tamayo, Holman, & Cook, 1973)

A brief experiment was conducted to evaluate the contribution of one factor to the outcome of Exps. IV and V. That factor, which might have emphasized the A characteristics of the mixed-mode filler, was the requirement that the subject verbalize his response to each filler item. This explanation seemed unlikely in view of the fact that verbal responses to filler items were required in Exp. II and we were able, nevertheless, to manipulate the direction of the asymmetry in that experiment by varying the mode of the filler task.

Method. Twenty-four subjects were run under conditions similar to those of Cond. VM of Exp. IV. The only change was to use a button press (like Exp. III) instead of a verbalized response to each filler item.

Results and discussion. If verbalization of the filler responses were responsible for the failure to obtain a release from PI for a V to A shift in Exps. IV and V, then the subjects in this experiment should have shown an abrupt improvement in recall of the A subset between Trials 3 and 4. The mean numbers of words correctly recalled from the A subset were 1.21, .71, .88, and .83, for Trials 1 to 4, respectively; for the V subset the corresponding means were 1.25, .83, and .75, respectively. Thus, these data show significant development of PI across the first three trials, $F(2,46) = 3.37$, $p < .05$, but recall was not significantly different for the A and V subsets, either over Trials 1 to 3 or on Trial 4, both $F$s $< 1$. There is no indication of a release from PI for the A items in these data, so it appears that the mode of the subject's response to the filler items does not influence the release from PI.

It is interesting to note that Hopkins, Edwards, and Gavelek (1971) reached a similar conclusion regarding verbalization of the memory items. Thus, it appears that presentation mode is important for both memory and distractor items, but that verbalization of either type of item has little effect on the release from PI following a shift in the mode of presentation of the memory items. This conclusion needs further empirical examination, since it clearly suggests that articulation by the subject has much different effects on memory than reception of an auditory stimulus, an implication which seems to disagree with the assumption of a number of memory theorists (e.g., Adams, 1967).

Exp. VII: Rate of Presentation

It is well established that rate of presentation and study mode interact in short-term memory (Laughery & Fell, 1969; Laughery & Pinkus, 1966;

Hackworth, 1964). The usual finding is that the A mode results in better recall than the V mode, but that the difference between the modes is greater with fast presentations than with slow presentations. On the basis of this evidence it seemed likely that rate of presentation should be a variable in the release-from-PI situation.

Method. Two rates of presentation of the study words were employed, One word every .75 sec (fast) and one word every 1.5 sec (slow). In order to reduce the design to a manageable number of groups, the mixed-list procedure of Exp. IV was used. Thus, there were eight groups formed by the orthogonal combination of rate of presentation (fast or slow), filler modality (A or V), and presentation modality of the study words (AM or VM). Thirty-two subjects were assigned to each condition.

Results. The mean total numbers of correct responses on Trials 1 to 3 are presented in Table 1 for each of the eight groups. These data were analyzed with study mode, filler mode, rate, and trials as variables. Obviously, there was significant development of PI, $F(2,496) = 93.69$, $p < .001$. The only other main effect was that performance was better with a V filler than with an A filler, $F(1,248) = 17.22$, $p < .001$. However, filler mode interacted with trials, $F(2,496) = 4.92$, $p < .05$, such that the difference between A and V fillers was slight on Trial 1 and increased over trials. Filler mode also interacted reliably with study mode, $F(1,248) = 8.50$, $p < .005$, such that A presentation was markedly better than V presentation with a V filler ($\bar{X} = 2.73$ versus $\bar{X} = 2.24$), but V presentation was slightly better than A presentation with an A filler ($\bar{X} = 2.12$ versus $\bar{X} = 2.00$); this result, of course, replicates the results for Trials 1 to 3 of Exps. II and III. Rate of presentation did not produce a significant main effect, but did interact reliably with study mode, $F(1,248) = 10.63$, $p < .005$, such that A presentation produced recall superior to that with V presentation when the rate was fast ($\bar{X} = 2.45$ versus $\bar{X} = 1.93$), but V presentation was superior to the A study mode with a slow rate ($\bar{X} = 2.43$ versus $\bar{X} = 2.28$).

Table 1

Mean Numbers of Words Correctly Recalled on Trials 1 to 3 of Exp. VII

| | | A Filler | | | V Filler | | |
|---|---|---|---|---|---|---|---|
| Condition | Rate | Trial 1 | Trial 2 | Trial 3 | Trial 1 | Trial 2 | Trial 3 |
| AM | Fast | 2.81 | 1.66 | 1.75 | 3.31 | 2.91 | 2.59 |
| AM | Slow | 3.06 | 1.81 | 1.16 | 3.25 | 2.41 | 2.25 |
| VM | Fast | 3.03 | 1.50 | 1.38 | 2.75 | 1.59 | 1.59 |
| VM | Slow | 3.28 | 2.19 | 1.59 | 3.28 | 2.22 | 2.31 |

Table 2

Mean Recovery Scores (Trial 4 Recall minus One-Half Trial 3 Recall)

for each Subset and Condition of Exp. VII

| | | A Filler | | V Filler | |
|---|---|---|---|---|---|
| Condition | Rate | Subset A | Subset V | Subset A | Subset V |
| AM | Fast | .09 | .47 | -.23 | -.27 |
| AM | Slow | .23 | .48 | -.09 | -.09 |
| VM | Fast | .19 | -.09 | .89 | -.20 |
| VM | Slow | .52 | .36 | .59 | -.03 |

The release from PI was assessed in terms of recovery scores. One modification in these scores was required because of the use of mixed lists in this experiment; for each mode of presentation on Trial 4 the maximum possible number of correct responses was two, whereas the number of correct responses possible on Trial 3 was four. To take account of this fact, the Trial 3 scores were all divided by two prior to computing Trial 4 minus Trial 3 recovery scores. The means of these scores are presented in Table 2. With the fast presentation rate, the results replicated those obtained in the previous experiments. With a V filler, and fast presentation, the only condition which had a mean recovery score significantly greater than zero was the VA shift, $t(31) = 6.14$, $p < .001$. With an A filler, and fast presentation, the mean recovery score was significantly greater than zero only for an AV shift, $t(31) = 3.49$, $p < .01$. Furthermore, with a V filler and slow presentation the only condition showing reliable recovery was the VA shift, $t(31) = 3.94$, $p < .001$; thus, the release from PI with a V filler seems to be independent of the rate of presentation. However, with an A filler and the slow rate, the mean recovery score was significantly greater than zero in the AV shift, $t(31) = 2.95$, $p < .01$, but also in the V to A shift, $t(31) = 3.00$, $p < .01$, and even in one of the control Conditions VV, $t(31) = 2.22$, $p < .05$.

Discussion. With a fast rate of presentation, the present results replicate those obtained in several of the previous experiments; namely, a release from PI is obtained for an A to V shift with an A filler task and only for a V to A shift when the filler is presented in the V mode. However, with the slower rate of presentation, the results are equivocal, particularly in the conditions with an A filler. Thus, no firm conclusion can be reached regarding the effect of rate of presentation on the release from PI following a mode shift. In retrospect, it was probably a mistake to use the mixed list.

The experiment was, however, successful in showing, once again, that rate of presentation and mode of presentation interact in short-term retention. Furthermore, the generality of this result was extended because of numerous differences in procedure between the present design and that

of previous experiments (Laughery & Fell, 1969; Laughery & Pinkus, 1966; Mackworth, 1964). The interaction of rate and mode is an empirical fact that is not adequately handled by current theories of memory.

## Characteristics of PI in this Situation

The experiments described in this section were designed to examine some of the characteristics of PI which develop over repeated trials of the distractor technique. One question concerns the relative contribution of long-term and short-term processes. A second question concerns the extent to which PI is manifest at the time of retrieval.

### Exp. VIII: The Dissipation of PI During a 120-Second Rest (Hopkins, Edwards, & Cook, 1972)

This experiment was designed to attempt to determine the relative roles of the long-term and short-term stores in the release-from-PI paradigm. Following several successive trials for the development of PI, a rest period of 0 to 120 sec was interpolated prior to the next trial. If the PI which develops with repeated trials reflected primarily short-term processes, it should be nearly dissipated within 120 sec. Conversely, long-term processes are implicated to the extent that PI is not dissipated within 120 sec.

Method. Each subject received four successive trials in a distractor-type short-term memory task. Half of the subjects received a shift in taxonomic class of the to-be-remembered words between the third and fourth trials, and half did not. For each subject, one of five rest intervals was interpolated between the third and fourth trials. Thus, there were ten independent groups formed by the orthogonal combination of two levels of shift in taxonomic class (shift and no-shift) and five different lengths of rest interval (0, 15, 30, 60, or 120 sec).

The stimulus words were selected from the animal name and tree name categories of the Battig and Montague (1969) norms. The word triads formed from these materials were each homogeneous with respect to category and had approximately equal mean category frequency. Eight different lists of four triads each were formed, four for shift conditions and four for no-shift conditions. For the no-shift conditions, two lists contained four triads of animal names and two lists contained four triads of tree names. For the shift conditions, two lists contained three triads of animal names followed by one triad of tree names, and two lists contained three triads of tree names followed by one triad of animal names. The assignment of lists to rest-interval conditions was counterbalanced.

The lists were presented to individual subjects via a Stowe memory drum. On each trial, the first advance of the drum exposed a triad of words for 5 sec. The second advance exposed a three-digit number for 15 sec; the subject was instructed to say the number aloud and immediately begin counting backward by threes. The third advance of the drum exposed three asterisks for 5 sec as the signal for the subject to recall the words aloud.

The subjects were instructed to recall the words in their left-to-right order of presentation, and were encouraged to guess if uncertain. Immediately after the recall period, the word triad of the next trial was presented.

Following the third trial the drum was stopped for 0, 15, 30, 60, or 120 sec. The subject was instructed to turn over a piece of paper and begin cancelling all of the As, Bs, and Cs, according to instructions given at the beginning of the experiment. When told to stop, the subject turned his paper face down, and looked back toward the window of the drum for the final trial.

Thirty-two subjects were assigned to each condition.

Results. The numbers of words correctly recalled are presented in Fig. 5. On the first three trials, there were no systematic differences in performance among the ten groups, so those data have been pooled for clarity of presentation in the left-hand panel of the figure. It may be seen that there was a marked decrement in performance from Trial 1 to Trial 3, $F(2,638) = 271.18$, $p < .001$, indicating the development of considerable PI.

Trial 4 performance is shown in the right-hand panel of Fig. 5 for each of the 10 groups. There was some concern about ceiling effects in the shift groups. However, this does not seem to have been an important factor, as evidenced by the fact that the standard deviations were similar for all 10 groups, ranging from .84 to .98 for the shift groups and from .84 to 1.20 for the no-shift groups. Performance on Trial 4 did tend to improve as the rest interval was lengthened, $F(4,310) = 2.66$, $p < .05$, indicating the dissipation of some PI. The shift conditions yielded better performance than the no-shift conditions, $F(1,310) = 84.45$, $p < .001$, and the interaction between these two variables was not reliable, $F(4,310) = 1.20$, $p < .10$. Thus, performance in the no-shift groups remained almost uniformly below that in the shift groups, indicating that substantial PI remained after two minutes.

Discussion. The present results seem to indicate a somewhat slower dissipation of PI than that obtained by Kincaid and Wickens (1970) in a similar experiment. One potentially important difference between this experiment and that of Kincaid and Wickens, which might have influenced the rate of PI dissipation, is the difficulty of the rest-interval activity. Kincaid and Wickens used Stroop color naming, which is surely more difficult and distracting than our letter cancellation task. The importance of the difficulty of the rest-interval activity was examined in Exp. IX by comparing PI dissipation during a very easy task (sitting quietly) with that during a difficult activity (multiplication problems). Another change made in Exp. IX was to lengthen the rest interval to 5 min, thus providing additional information regarding the rate of recovery from PI.

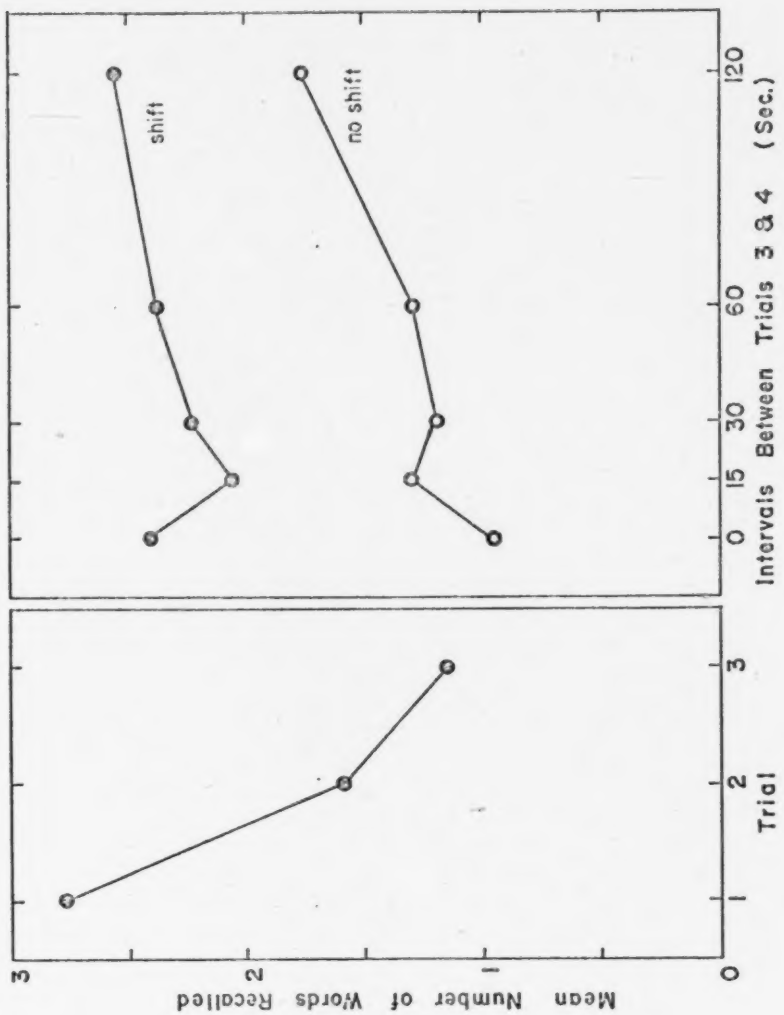


Fig. 5. Mean numbers of correct responses in Exp. VIII.

Exp. IX: Rest-Interval Difficulty and the Dissipation of Proactive Interference (Hopkins, Edwards, & Cook, 1972)

Method. The materials and procedure were identical to those of Exp. VIII with the following two exceptions. First, only one rest interval was used: 5 min. Secondly, two different rest activities were used. Half of the subjects were given a sheet of ten problems requiring the multiplication of a two-, three-, or four-digit number by another two-, three-, or four-digit number, and asked to complete as many as possible in the allotted time. The remaining subjects were given no specific rest activity and were simply asked to sit quietly. Thus, the design was a 2 by 2 factorial, with two levels of shift (shift and no-shift) and two levels of rest-interval activity (none and multiplication). Thirty-two subjects were assigned to each condition.

Results. Overall mean recall scores on Trials 1, 2, and 3 were 2.84, 1.66, and 1.13, respectively, almost identical to Exp. VIII. For the multiplication conditions, the mean recall on Trial 4 was 2.75 in the shift condition and 2.31 in the no-shift condition; the corresponding means in the conditions with no rest-interval activity were 2.66 and 2.34, respectively. Trial 4 performance in the shift groups was superior to that in the no-shift groups, $F(1,124) = 5.85$, $p < .025$. Rest-interval activity was not a reliable variable, either in main effect or in interaction with shift condition, both $F$s $< 1$.

Discussion. The difference between the results of Exp. VIII and those of Kincaid and Wickens (1970) are probably not attributable to the difficulty of the rest-interval activity. Even though some differences between the studies do remain, one must not lose sight of the similarities. In each case, a substantial proportion of the PI remains after a rest interval of 2 to 5 min. Thus, some of the PI may be due to long-term, as opposed to short-term, processes. Equally important, however, is the fact that at least 50% of the PI does dissipate within 2 min and, therefore, can reasonably be attributed to short-term processes. The latter conclusion is quite different from that recently reached by Craik and Birtwistle (1971). Those investigators used a task requiring free recall of successive 15-word lists and concluded that PI develops in the long-term store but not in the short-term store. On a theoretical level, it may be assumed that the last few items of a free recall list are recalled from the short-term store; on an empirical level, however, the laws inferred from the free recall task (used by Craik & Birtwistle) may be quite different from those inferred from the distractor task generally used in the release-from-PI paradigm.

On the basis of the results of Exp. VIII and IX, and those obtained by Kincaid and Wickens, it appears that performance in the released-from-PI paradigm is mediated by a combination of long- and short-term memory processes. The results of filler modality manipulations in Exps. II through VII are interpreted, however, as evidence that short-term processes are dominant in the release from PI following a shift in mode of presentation of the memory items.

Exp. X: Retrieval Processes in PI with Experimentally Familiarized Materials

All of the experiments described above, and most of those in the literature, have used rather brief recall periods. Thus, a large proportion

of the observed PI may be due to output interference or retrieval difficulties arising from time pressure provided by a brief recall period. In order to conclude that retrieval is a factor, however, it is necessary to take several steps.

First, it must be shown that the items are initially registered in the short-term store. This can be accomplished by testing some subjects after a very brief retention interval. Intuitively, one would expect that a subject would be able to recall three words immediately after their presentation, no matter how much PI had been developed. This would be evidence that the items are registered in the short-term store.

Secondly, it is necessary to establish that the items remain in memory throughout the trial, but are simply not accessible or recallable during the time of test. This can be accomplished by providing a test for recall of all the experimental words at the conclusion of the experiment. Then, those words recalled on this test can be assumed to have been present in memory at the time of the tests for short-term retention.

If it is established both that an item was registered in the short-term store, and that it was present in memory in a post-experimental test, then an inability to recall that item in the distractor test would seem to be due to retrieval difficulties.

In the first experiment of this series, the target words were familiarized by simply having the subject learn to freely recall the entire set of words prior to the main portion of the experiment. Then subjects participated in three successive trials of the distractor task with a retention interval of either 2 or 16 sec. Five minutes after these trials, each subject was given a variety of tests for long-term memory of the experimental items.

This experiment will not be described in detail here because Exp. XI, which was designed later, provides a much neater test of the hypothesis. Only the general trend of the results need be noted. Relative to appropriate controls, familiarization did improve recall in the distractor task, but only slightly and it had no differential effect on the development of PI. More importantly, there was little PI with the 2-sec retention interval (items were being registered in the short-term store), but there was substantial PI with the 16-sec retention interval, even for items which were later found to be recallable from long-term memory. These results are consistent with the hypothesis that retrieval difficulties play a major role in the development of PI.

Exp. XI: PI as a Function of Retention Interval with Items Known to be Present in Memory

Exp. X had the disadvantage that it required pretraining or familiarization of the experimental words to assure that a large proportion of those words would be available in the long-term store. In Exp. XI, the to-be-remembered materials on each trial were the names of three months of the year. Clearly, every subject has these items well represented in the long-term store, so the familiarization can be accomplished by simply informing the subject that these are the materials to be used.

Method. Each subject received four successive trials in a short-term memory distractor task. Twenty-four subjects were assigned to each of four independent groups, differing with regard to the length of the retention interval on each trial (0, 4, 8, or 16 sec).

The to-be-remembered materials were the names of the twelve months of the year. Four triads, each consisting of three different month names, were formed by randomly selecting, without replacement, one month from each successive third of the calendar year for each triad. The trial positions of the four triads were counterbalanced, resulting in four lists. Equal numbers of subjects in each group were assigned to each list. The distractor activity was backward counting by threes from a randomly selected three-digit number.

On each trial, a triad of month names was presented for 4 sec. This was followed by a three-digit number. The subject said the number aloud, and then began counting backward by threes from that number as rapidly as possible. After the period of backward counting, the word "recall" was exposed for 4 sec, during which the subject was to recall the three month names that had been presented on that trial. For the 0-sec retention interval group, the study words were followed immediately by the word "recall." For the two groups with 8- and 16-sec retention intervals, the three-digit number for backward counting changed every 4 sec. All materials were presented via Stowe memory drum.

Results. The mean numbers of words correctly recalled on each trial are presented in Fig. 6. It may be seen that there was no PI with a 0-sec retention interval; all 24 subjects in that group perfectly recalled the three month names on each trial. For the other three groups, there was a significant PI decrement across trials, $F(3,207) = 37.45$, $p < .001$, and the amount of PI was directly related to the length of the retention interval, $F(2,69) = 8.14$, $p < .001$. The interaction of these variables was not reliable, $F(6,207) = 1.40$, $p > .20$.

Discussion. These results speak for themselves. The memory items are available in long-term memory for every subject. Furthermore, the perfect retention on all trials with a 0-sec retention interval indicates that all items were initially recallable from the short-term store. Nevertheless, with a typical retention interval of 4 to 16 sec, and a recall interval of 4 sec, PI does develop. Thus, the observed PI is apparently due to retrieval difficulties.

## Exp. XII: Mode of Presentation and PI with a Long Recall Period

To the extent that the accumulation of PI is due to retrieval problems, PI should be reduced by using a much longer recall period. This experiment was designed to provide evidence on that question. In addition, the A and V modes of presentation were directly compared.

Method. Four independent groups were formed by the factorial combination of two modes of presentation of the study items (A or V) and two modes of distractor activity (A or V). Twenty-four subjects were assigned to each group.

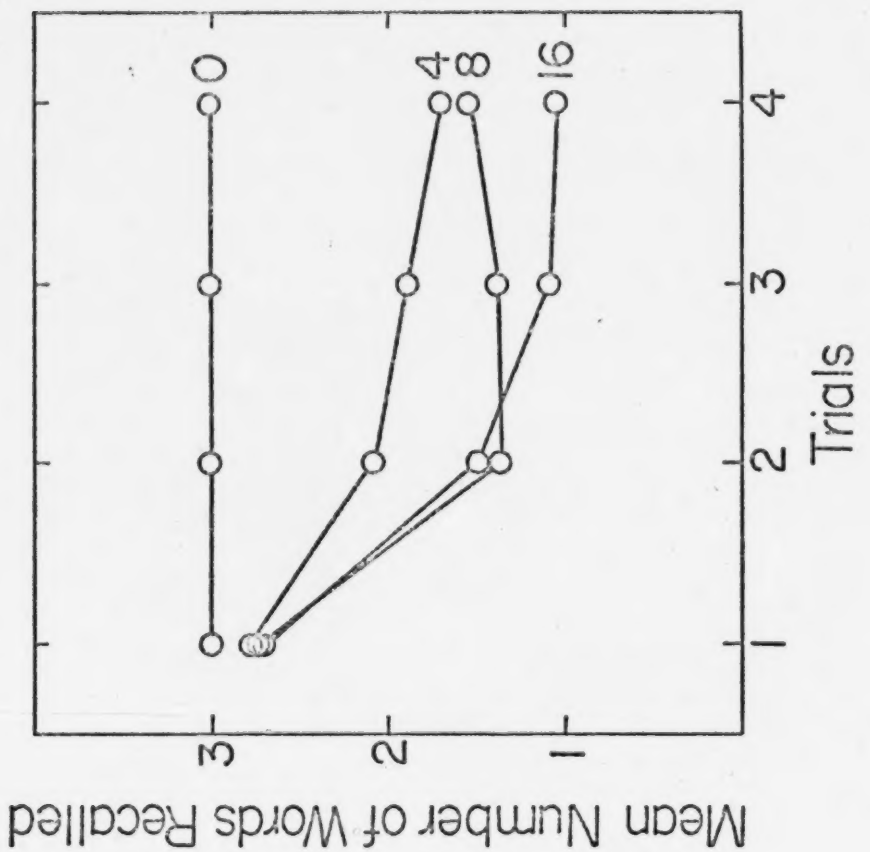


Fig. 6. Mean numbers of correctly recalled month names in Exp. XI.

The lists of study items were the same as for Exp. XI, and the numerical addition task of Exp. III was used as filler activity. The recall interval was 25 sec, and subjects were given feedback by the experimenter as the recall took place. For each correctly recalled word the experimenter said "right," and he said "wrong" for each incorrectly recalled word. The subject was permitted as many attempts as necessary to recall the three correct words. Once a subject had recalled all three words correctly, or had recalled as many as he could, he was instructed to simply sit quietly until the end of the 25-sec recall period, when the next trial began.

Results. It was hoped that the number attempts required to correctly get the three words on each trial could be the major dependent variable, providing a direct index of the amount of retrieval difficulty. However, of the subjects who did not recall the three correct words immediately, a large proportion never did recall all three words correctly. Thus, this dependent variable could not be used.

The data were simply scored in terms of the number of correctly recalled words in the first three attempts. The means of this response measure are presented in Table 3. It may be seen that very little PI developed, although the decrement in performance across trials was reliable, $F(3,276) = 7.73$, $p < .001$. Recall was better with a V filler than with an A filler, $F(1,92) = 14.35$, $p < .001$. The data are suggestive of the interaction between filler mode and study mode obtained in Exps. II and III; however, this effect was not statistically reliable, $F(1,92) = 3.01$, $p \approx .08$, probably because overall performance was so high that differences among the groups were masked by ceiling effects.

Table 3

Mean Numbers of Correct Responses in Exp. XII

| Study Mode | Filler Mode | Trial 1 | Trial 2 | Trial 3 | Trial 4 |
|---|---|---|---|---|---|
| A | A | 2.58 | 2.12 | 1.92 | 2.29 |
| A | V | 2.92 | 2.54 | 2.58 | 2.67 |
| V | A | 2.62 | 2.37 | 2.37 | 2.04 |
| V | V | 2.71 | 2.54 | 2.42 | 2.42 |

Discussion. This experiment was unsuccessful in its attempt to measure retrieval difficulty directly by a new dependent variable. Nevertheless, the results are consistent with the interpretation that PI is due, in part, to retrieval difficulties, since allowing subjects essentially unlimited time for recall greatly reduces the amount of observed PI.

Taken together, then, the last three experiments on retrieval suggest that problems at retrieval are a major component of PI. However, they do not invalidate the use of the release-from-PI paradigm as a procedure for the study of encoding. It is still the case that materials which don't

interfere with one another, at retrieval or at any other time, must be represented differently from on another in memory. Thus, a reduction in interference following a shift in mode of presentation must mean that the pre-shift and post-shift materials have been encoded differently.

## Other Procedures for Studying Encoding

### Exp. XIII: Direct Measurement of Memory for Mode of Presentation (Hopkins, 1972)

Encoding, per se, is an unobservable process and must be studied by indirect methods. However, some of the results of encoding are directly observable. For example, one can determine whether or not information about stimulus modality has been encoded by simply asking the subject to identify the mode of presentation of a particular stimulus. In this way one has a direct test of whether or not mode of presentation is an attribute that is represented in memory. The present experiment used this technique in a situation which most probably tested long-term, rather than short-term memory, although the technique could be extended to the study of short-term processes. In addition, this particular experiment provided a test of the hypothesis that retrieval and output decision (based on the attributes of a retrieved item) are independent processes.

The general procedure is to present a free recall list composed of some A words and some V words. Following free recall of the list, the subject is asked to identify the mode of presentation for each member of the list. At least two related experiments have recently been reported, one by Bray and Batchelder (1972) and one by Madigan and Doherty (1972). Those reports suggested that subjects can make accurate judgments of presentation mode, even in situations for which free recall isn't organized by mode and for which overall recall is not influenced by presentation modality.

Suppose that recall is made contingent on the modality judgment, instead of separating recall and modality judgments as in the previous experiments. For example, we might ask the subject to recall only the A words. This task will be called "limited recall," as opposed to free recall. Can we predict performance in limited recall from performance in separate tests of free recall and mode identification?

Assume that recall of an A word in the limited recall task is a two-stage process. First, the word must be retrieved, just as in free recall. Secondly, the subject must make a decision regarding the mode of presentation of that retrieved word. If the subject decides the retrieved word is an A word, he recalls it; otherwise, the subject rejects that word and searches memory for a different word. If we assume that the processes of retrieval and mode identification are independent, then we can make a specific prediction. In fact, Bray and Batchelder (1972) did report evidence for such independence. Given this model of two independent processes, then, recall probabliity with instructions for limited recall should be equal to the probability of freely recalling an A word and the probability of identifying it as an A word. These two probabilities can be estimated from the performance of a group of subjects who freely recall the words and then make modality identifications. For example, suppose the probability of recalling an A word in free recall is .6, and the probability of correctly identifying

an A word is .8. According to this model, the predicted probability of recalling an A word in the limited recall task is .48. The present experiment provides a test of this model, as well as additional information regarding the subject's ability to remember and use mode of presentation information.

Method. Twenty subjects were assigned to each of three groups: recall All words, recall A words only, and recall V words only. The subjects were tested individually on a mixed list consisting of five common words presented in the V mode and five common words presented in the A mode. Each list was scrambled so that no more than two successive words were presented in the same mode. The V words were presented by memory drum and the A words were spoken once by the experimenter as a blank was shown in the window of the memory drum. Initially, the subjects were simply instructed to study each word as it was presented so that all the words could later be recalled. Then the list was presented once at a rate of 4 sec per item. Following study, the appropriate instructions for recall were given to the subject, and any questions were answered. This instruction period took about 30 sec, so we presume that subsequent recall was predominately from the long-term store. The free-recall was paced at a 2-sec rate. All subjects were given the same time for recall, sufficient for recall of all ten words. Following recall, the subject was instructed for the modality identification task. For this task, the study words were presented at a 2-sec rate and the subject was to say "auditory" for each A word and "visual" for each V word; the subject was instructed to respond to each word, guessing if uncertain.

Table 4

Recall and Identification Scores for Each Condition of Exp. XIII

| | Group All | | Group A | | Group V | |
|---|---|---|---|---|---|---|
| | A words | V words | A words | V words | A words | V words |
| Probability of Correct Word Recall | .53 | .56 | .44 | .23 | .26 | .66 |
| Probability of Correct Modality Identification | .73 | .84 | .77 | .83 | .72 | .83 |
| Predicted Probability of Correct Word Recall | | | .39 | .09 | .14 | .47 |

Results. The results are summarized in Table 4 for the major dependent variables. Consider first the data from Group All. The difference in recall probability between A words and V words was obviously a small one, $t < 1$. It is also clear that the subjects were able to make reasonably accurate mode identifications. The fact that V words were better identified than A words, $t(19) = 2.61$, $p < .02$, is opposite to the difference obtained by

Bray and Batchelder (1972). This difference probably depends on the procedure, and the superiority of V to A identification in the present results may be due to the fact that all words were presented in the V mode at the time of test.

Several measures of recall organization were also considered for Group All. First, the mean serial position in output was 3.28 for A words and 3.18 for V words; thus, there was no tendency to recall A words before V words and vice versa. A variety of clustering measures were computed, and in no case was the amount of observed clustering significantly different from chance. For example, the z-score clustering index suggested by Frankel and Cole (1972) was .01 when words were classified on the basis of their actual mode of presentation and -.18 when classified on the basis of the subject's subsequent mode identification responses. Thus, there was no indication of clustering of recalled words by mode of presentation.

Finally, the dependence of correct identification on recall was checked in Group All. One might expect that recalled words would be better remembered in all respects, so that their presentation modes would be more accurately identified than those words that were not recalled. The conditional probabilities of correct identification given recall and given no recall were .70 and .78, respectively, for A words and .88 and .80, respectively, for V words. The hypothesis of independence could not be rejected by a chi-square test for either A words or V words, both $\chi^2 < 1$. Thus, for the group instructed to freely recall all of the words, the results are entirely consistent with those obtained previously: subjects can remember mode of presentation, but this memory appears to be independent of recall, and free recall is not organized by mode of presentation.

The results for the other two groups, A and V, provide information regarding a situation in which the subject is, in effect, instructed to organize his recall by mode of presentation. It is evident from the results shown in the table that subjects can follow this instruction. When the subject is instructed to recall only A words, he does make mistakes but recalls more A words than V words, $t(19)$ 2.58, $p < .02$. Similarly, when the subject is instructed to recall only V words, significantly more V words than A words are recalled, $t(19) = 5.63$, $p < .001$. Mode identification seems to occur in these groups with the same accuracy as in Group All.

The data in the last line of the table provide a test of the model outlined in the introduction. The data from Group All were used in computing these predicted recall probabilities for Groups A and V. For example, in order for a subject in Group A to recall an A word, he must be able to both recall the word and identify it as an A word. The respective probabilities, estimated from Group All, are .53 and .73, so the predicted probability is the product .39. In order for a subject in Group A to recall a V word, he must be able to recall the word with probability .56, but then misidentify it, with probability 1-.84; the product of these probabilities is .09. The two predicted probabilities for the V group were obtained in a similar manner. It may be seen that each of the predicted recall probabilities seriously underestimates the corresponding obtained value.

Discussion. Clearly, the simple and intuitively attractive model suggested here is incorrect. One possibility, which could have produced the obtained results, is that subjects in Groups A and V were simply using a different criterion to decide the mode of a retrieved word than the criterion used by subjects in Group All in making their mode identifications. Rather than pursuing the model without more data, however, the interesting findings will simply be summarized. It is apparent from this experiment, as well as from those by Bray and Batchelder (1972) and Madigan and Doherty (1972), that subjects do retain modality information, but do not ordinarily use that information to organize their recall. For this reason, it seems unlikely that A and V words are stored as separate sets in memory. The results from the limited recall task, however, indicate that subjects can make their recall dependent on modality information when instructed to do so.

It seems that the limited recall task may prove extremely useful for the study of attributes of memory and of retrieval processes. The experiment described here was a preliminary effort in the investigation of modality effects in the long-term store. A related procedure could also be developed for study of the short-term store. For example, one might present a very few items in mixed modes, distract the subject, and then present a probe item, asking the subject to indicate the modality in which the probe was originally presented. Since accuracy would likely be extremely high, it would be necessary to use some other dependent variable, such as the speed with which the decision is made.

## Exp. XIV: Acoustic and Visual Similarity in Same-Different Letter Identification Judgments

This experiment was conducted by Richard J. Boylan in partial fulfillment of the requirements for the Ph.D. in psychology, under the direction of the principal investigator. Although the data are all collected, Mr. Boylan has not finished the analysis and interpretation of the data. Consequently, the description of this experiment must be brief and more superficial than that for most of the other research in this report.

The background for this experiment comes from the general notion that human information processing proceeds by stages, and from the idea that separate stages of processing can be isolated by studying the interactions of independent variables in determining reaction times (Sternberg, 1969). In particular, a number of indications suggest that character recognition might consist of two stages (cf., Neisser, 1967). In the recognition of letters of the English alphabet, for example, it appears that an early stage consists of feature extraction and should be highly dependent on visual similarity of the characters to be discriminated; a second stage depends on naming of the perceived letter and should be dependent primarily on the acoustic similarity of the letters to be discriminated. Mr. Boylan was interested in these stages of stimulus encoding, and reasoned that if the above interpretation were correct, then one would expect an interaction between the type of similarity and the time allowed for processing of the letters.

To investigate this problem, an experiment was designed in which the same-different task was employed. In this task, the subject is presented with two letters in rapid succession and must decide whether they are the same or different. The time to make this decision is measured. The letters used were from sets that were either the same (such as both Cs), or differed in one of four systematic ways: acoustically similar (such as C-E), visually similar (such as C-O), similar on both dimensions (such as C-G), or similar on neither dimension (such as C-F). The first letter was presented for 20 to 1000 msec and the second letter was presented for 20 to 1000 msec, with a constant interval of 50 msec between the two letters. The subject pushed one of two buttons for each pair, indicating whether the letters were the same or different.

If two separate stages were being influenced differentially by acoustic and visual similarity, then the temporal variables and the type of similarity should have interacted in determining the time required to make a different judgment. Preliminary analyses of the data suggest that this interaction was not obtained and that, therefore, the hypothesis of separate stages is incorrect or the experimental method inappropriate for the study of these stages.

Exp. XV: Pronunciation Effects in Forced-Choice Recognition Memory (Hopkins & Edwards, 1972)

It was noted in the discussion of Exp. VI that verbalization of the filler items, as well as verbalization of study items, does not appear to have the same consequences as A presentation of these types of items. A number of memory theories (e.g., Adams, 1967) seem to suggest that A presentations and vocalized V presentations should have very similar effects. Furthermore, a variety of studies clearly show that pronunciation or vocalization is a variable in short-term retention (e.g., Peterson & Johnson, 1971; Tell, 1971; Levy, 1971). Experiments XV and XVI provide some information regarding the effects of pronunciation of study words on encoding and subsequent recognition memory. These studies did not investigate modality effects, per se; instead, they were designed within the context of frequency theory. They are, however, clearly related to the problem of encoding and to differential encoding and retention of pronounced and silently-studied items.

The frequency theory was proposed by Ekstrand, Wallace, and Underwood (1966) for verbal discrimination learning, and has been extended to other types of recognition memory by Underwood and Freund (1970). This experiment was designed to test a prediction from frequency theory, the prediction that recognition memory for verbal units will be improved by pronunciation of those units.

According to the frequency theory, frequency is one of the principal memory attributes used in a recognition test. That is, the subject is presumed to distinguish previously studied (old) items from distractor (new) items on the basis of a frequency differential, the old units having a situational frequency of one, the new ones a frequency of zero. Underwood and Freund (1970) tested this theory by manipulating the frequencies of both old and new items; in support of the frequency theory, they found that correct identification of an old word was directly related to the number of its

repetitions and inversely related to the number of repetitions of the new word with which it was paired.

One of the assumptions of frequency theory is that the pronunciation of verbal units increases their apparent frequency. This assumption has received indirect support from numerous verbal discrimination experiments (Hopkins & Epling, 1971; Underwood & Freund, 1968). In a more direct test, Hopkins, Boylan, and Lincoln (1972) found that pronunciation did increase judged frequency, but only when pronunciation was manipulated in a mixed list, that is, when the subject pronounced some of the experimental words and not others. An obvious prediction is that pronunciation should improve recognition performance, but only in mixed lists. However, the distractor items of a recognition test have not been presented before the test and, consequently, have not been pronounced in the experimental situation. Thus, the test comparisons involve both pronounced and unpronounced items, regardless of the study conditions. Based on this analysis, it can be predicted that pronunciation should facilitate recognition memory for both mixed and unmixed lists. This experiment tested this prediction in a forced-choice test situation.

Method. Each subject studied a list of 100 words, of which 50 were underlined and 50 were not. Recognition memory was tested by a two-alternative forced-choice procedure. Four independent groups received different study instructions. One group (Group U) pronounced each underlined study word once as it was presented. The second group (Group NU) pronounced only the nonunderlined study words. Group B pronounced both underlined and nonunderlined words. Group N pronounced neither type of study word, that is, all the words were studied silently.

The materials were 200 three- to six-letter nouns taken from among the 1000 most frequent words in the Thorndike-Lorge count. The words were randomly assigned to four subsets (A, B, C, or D) of 50 words each, and four different study lists were prepared. In List 1, subsets A and B were the study words with the members of subset A underlined. Subsets A and B were also the study words of List 2, but the members of subset B were underlined. Subsets C and D served as distractors for the test trials of Lists 1 and 2. Lists 3 and 4 were constructed in a similar manner with subsets C and D as old words and subsets A and B as new words. The subsets forming a study list were scrambled so that no more than four underlined words occurred in succession. The forced-choice test lists were formed by randomly pairing distractor words with study words to form 100 pairs, each containing one old and one new word; these pairs were randomly ordered on a test sheet with 25 pairs in each of 4 columns. The assignment of lists to groups was counterbalanced.

The appropriate study list was presented to each subject via a Stowe memory drum at a 2-sec rate. The subject was simply told to try to remember the study words and to pronounce them according to instruction. The subjects in Groups B and N were told that the underlining was for another purpose and could be ignored. At the conclusion of the study trial, there was approximately a 30-sec pause for the reading of the test instructions. The subject was then given a test sheet and told to respond to each item, guessing if uncertain. The subjects were to indicate whether the right or left member

of each pair was the old one. Each subject was told to work as rapidly as possible, but no time limit was imposed.

Results. The overall mean time to complete the test sheet was 6.15 min, and did not differ significantly for the four instruction groups. The mean numbers of correct identifications are presented in Table 5 for each condition. It may be seen in the table that pronounced words tend to be better recognized than unpronounced words, but only in Groups U and NU.

Table 5

Mean Numbers of Correct Responses in each Condition of Exp. XV

| | Pronunciation Condition | | | |
|---|---|---|---|---|
| Item type | B | N | U | NU |
| Underlined | 38.35 | 37.30 | 40.10 | 35.45 |
| Not-underlined | 38.45 | 36.65 | 35.10 | 38.75 |

The data were analyzed with group and underlining as factors. The only reliable source of variance was the interaction of these variables, $F(3,76) = 10.83$, $p < .001$. The nature of this interaction was examined by follow-up comparisons using Scheffe's (1959) criterion; according to that criterion, the F value corresponding to a particular follow-up test must be greater than 8.25 to be significant at the .05 level. The numbers of correct identifications were not significantly different for underlined and nonunderlined words in either Group B or Group N, both $F$s $<1$; underlined words were better recognized than nonunderlined words in Group U, $F(1,76) = 23.18$, whereas the reverse was true in Group NU, $F(1,76) = 10.10$. The effect of pronunciation was not reliable in the between-group comparison of Group B with Group N, $F < 1$.

Discussion. It seems clear that pronunciation facilitated recognition memory, but only in situations where the subject had pronounced some of the study words while others were studied silently. These results will be discussed after presentation of the results for Exp. XVI.

Exp. XVI: Pronunciation Effects in Old-New Recognition Memory (Hopkins & Edwards, 1972)

The rationale for this experiment was precisely the same as for Exp. XV. This experiment used old-new recognition tests, rather than forced-choice, to extend the generality of the results of Exp. XV.

Method. The design, materials, and procedure were identical to Exp. XV with the following exceptions. Recognition memory was tested by an old-new procedure. The old-new test lists were prepared by randomly ordering the entire 200 words in seven columns on a test sheet. The subjects were to identify each old item with an "O" and each new item with an "N." As in Exp. XV, twenty subjects were assigned to each of the four instruction groups.

Results. The overall mean time to complete the old-new test sheet was somewhat longer than the forced-choice test sheet of Exp. XV, with a mean of 8.27 min, but again the completion time was not reliably different for the four groups. The mean numbers of correct identifications are presented in Table 6 for each group, where correct recognitions are presented separately for old and new items.

Table 6

Mean Numbers of Correct Responses in Each Condition of Exp. XVI

| | Pronunciation Condition | | | |
|---|---|---|---|---|
| Item type | B | N | U | NU |
| Old-Underlined | 34.35 | 33.35 | 34.80 | 28.75 |
| Old-Not Underlined | 32.45 | 33.70 | 28.50 | 34.35 |
| New | 76.40 | 72.70 | 73.00 | 69.00 |

Any difference among the groups in correct recognition of new items could be mediated by differential response biases; hence, it is important that such differences be small. The observed differences are small, and the effect of instruction group on new items was not significant, $F < 1$. For the old items, only the interaction between groups and underlining was significant, $F(3,76) = 10.09$, $p < .001$. Using Scheffe's criterion, as outlined for Exp. XV, the effect of underlining was not significant for either Group B, $F(1,76) = 1.49$, or Group N, $F < 1$. However, underlined items were better recognized than nonunderlined items in Group U, $F(1,76) = 16.34$, and underlining resulted in poorer performance in Group NU, $F(1,76) = 12.91$. As in Exp. XV, the effect of pronunciation did not show up in the comparison of Group B with Group N, $F < 1$.

Discussion. The results of Exps. XV and XVI are remarkably similar. Pronunciation has no effect on recognition memory when independent groups are used in the comparison (Group B versus Group N). However, pronounced words are better recognized than unpronounced words when a mixed list is used, that is, in Groups U and NU. The latter result is apparently due to pronunciation rather than underlining, per se, since underlining was not a variable in either Group B or Group N in either experiment. These conclusions are identical to those of Hopkins, Boylan, and Lincoln (1972) regarding the effects of pronunciation on frequency judgments, but the failure to find a pronunciation effect in the unmixed lists is contradictory to the prediction made in the introduction to Exp. XV. These results suggest that the effects of pronunciation are relative in the sense that the subject must experience the contrast between pronounced and unpronounced items. Furthermore, at least in the case of recognition memory, the fact that both pronounced and unpronounced words occur on test trials is not sufficient to produce the pronunciation effect; the study list must be mixed with respect to pronunciation. For this reason, it is tempting to conclude that the pronunciation effects are study-trial or encoding effects. On the other hand, Underwood and Freund (1970) found that increasing the frequency of old items in a

forced-choice test, by repeating those items as distractors, reduced recognition accuracy. Thus, at least some of the effects of frequency, per se, occur on test trials and, consequently, pronunciation and frequency effects may be somewhat different. The present evidence on this matter is, of course, indirect, but the conclusion is similar to that reached by Hopkins, Boylan, and Lincoln (1972) on the basis of different evidence.

Another aspect of these results which requires comment is that there is little, if any, absolute improvement in performance due to pronunciation. Rather, it seems that not pronouncing some items reduces their subsequent recognizability. This is particularly apparent in the results from Exp. XVI. For example, in that experiment performance on underlined words in Group U was not significantly better than the pooled mean from Groups B and N, $F(1,76) = 1.18$, but performance on nonunderlined words of Group U was significantly lower than the pooled mean for Groups B and N, $F(1,76) = 16.22$. Similarly, in comparing the performance in Group NU with Groups B and N, pronunciation did not improve recognition, $F < 1$, but silent study lowered recognition performance, $F(1,76) = 14.63$. The results of Exp. XV suggest a similar conclusion, but are not so striking in this regard. Thus, the effect of pronunciation appears to lie in a decrement in performance for unpronounced words rather than an increment for recognition memory of pronounced words.

It appears, then, that pronunciation of a verbal unit can improve subsequent recognition of that unit, in agreement with the frequency theory. The improvement in recognition memory is, however, relative in two ways. First, the subject must pronounce some items and not others in order for the effect to be observed; manipulation of pronunciation responses for independent groups has no effect on recognition performance. This, in turn, implies that pronunciation effects are encoding effects rather than being due to processes occurring at the time of test. The second way in which pronunciation effects are relative is that the difference in recognition of pronounced and unpronounced words seems to be due at least as much to decreased recognizability of unpronounced words as it is to increased recognizability of pronounced words. The two types of "relativity" are probably not independent, and may well be due to the same underlying mechanisms. They are, however, not immediately predictable from the frequency theory in its present form.

## Chapter 3: CONCLUSIONS AND RECOMMENDATIONS

The first subsection of experiments in this report (Exps. I through VII) are most significant for purposes of this project, as well as for theories of memory. Those experiments strongly support the hypothesis that A and V materials are represented differently in the short-term store, that is, encoded differently. This is not to say that an auditory and/or articulatory code does not play a major role in verbal short-term memory, or even that the code for V items is visual or imaginal in nature. It is simply suggested that not all verbal items are stored as though they had been presented in the A mode, and that theories of memory will need to take account of this fact. A particularly important variable in the encoding of A and V materials is the mode of presentation of the rehearsal-prevention activity. In fact the asymmetry in the recovery from interference following a shift in presentation modality can be completely reversed by manipulating the distractor modality. This result suggests that the type of encoding used by the subject is task dependent, and probably under the subject's control. The latter suggestion is in need of further investigation, and one avenue of potentially fruitful research would be to direct more attention to the subject's control processes and to individual differences in those processes.

The experiments of the second subsection (Exps. VIII through XII) were designed to learn more about the PI effects that are being used to study encoding processes. It seems clear from those experiments that the PI which develops over successive short-term retention tests probably reflects both short-term and long-term processes, and is due in large part to retrieval difficulties. As discussed in detail in the results section of this report, these findings regarding PI do not alter the main conclusion concerning differential encoding of A and V materials. They do, however, suggest that PI is a rather complicated phenomenon.

Since PI effects are complex in themselves and provide rather indirect information about the encoding process, it seems important to try other types of situations for the study of encoding. This was the purpose of the experiments described in the third subsection (Exps. XIII through XVI). One procedure which seems extremely well-suited for the study of attributes of memory is that of Exp. XIII, the attribute-identification situation.

One very important aspect of modality-specific encoding has not received a great deal of attention in this report. That aspect is the function of this type of encoding. Given that modality-specific encoding can and does occur in some situations, of what use is it? Does it facilitate memory search? Does it facilitate retrieval and output decisions? These questions will need answering before the fact of modality-specific encoding can be used in applied situations.

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